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Managing Logistic System of Waste for Crude Palm Oil Industry

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Abstract
The crude palm oil industry is an agro-industrial commodity which has a strategic value to be developed for Indonesian economy. However, there are a number of environmental problems at the factories, such as high water consumption, the generation of a large amount of wastewater with a high organic content, and the generation of a large quantity of solid wastes and air pollution. In this paper we propose a multiobjective integer programming model for managing business environmental risk in a crude palm oil manufacture which gives the best possible configuration of waste management facilities and allocates wastes to these facilities. We develop an interactive approach for tackling the multi-objective model.
***Keywords**: Crude-Palm oil, Environmental Production Planning, Multi-objective programming, Modeling, sustainable optimization.*

1. Introduction

Originally, the oil palm was found in the tropical rain forest of West Africa. At that time it was used as a source of oil and vitamins. Today the oil palm tree can be found in many tropical countries in Asia, Africa and Latin America. Oil palm seeds of the Dura variety were introduced to Indonesia and Malaysia in 1848 and 1875, respectively. The oil palm cultivation in South East Asia, such as, in Indonesia, Malaysia and Thailand, produce about 80% of the world's palm oil [4].

Refined palm oil is used in both food and non-food applications. To most users, the palm oil is known as refined golden yellow oil. In the refining process, palm oil can be divided in fractions at room temperature; liquid and higher- melting point substance. Various grades of oleins and stearins are available commercially. Palm oil is used in various food products, such as cooking oil, margarine, frying fats, shortenings, vanaspati, non-dairy creamer, etc. Palm oil is also used in non-food products. It can be substitute products derived from petrochemicals. Due to an increasing environmental awareness, these products have a bright future, particularly, in producing biodiesel.
The crude palm oil industry plays an important role for economic development Despite obvious benefits of this industrial development, it contributes to environmental degradation from both input and output sides of its activities. On the input side, crude palm oil mill uses much water in production process and consumes high energy. On the output side , manufacturing process generates large quantity of wastewater, solid waste/ by-product and air pollution.

Most of media in Indonesia have increased exposure on environmental issues regarding with the escalating increase in the environmental resources depletion, human toxicity levels and ecosystem quality deterioration. Therefore most of the Indonesian society have become more aware of environmental damage. Companies, in turn, are investing more in the assessment of the environmental impact of their products and services.

Industrial waste handling is the final and critical step for industrial pollution control. It is also an important issue to cleaner production and sustainable development. Industrial eco-systems are the environmental friendly systems for industrial waste recycling, resembling the food chains, food webs and the nutrient recycles in natural environment [7]. They are much more environment friendly compared to other waste treatments such as incineration, solidification and landfill because:
a. It transforms the harmful component of waste into usable substance.
b. It slows down the depletion of primary resources in industrial production.

However in this situation there would be one question come up, such as, 'how much cost should be needed to increase the quality of the environment'. In scientific terms it can be stated as, what is the trade-offs between environment burden and economic activities. Furthermore we need to get the best solution for the trade-offs for ecology and economic interest ([8]).
On the normative and quantitative terms, these questions have led to the concept of trade-offs and efficient frontiers for business and the environment [6, 1]. The main idea is to determine the set of solutions in which it is not possible to

decrease environmental burden or to increase total environmental quality of each environmental category, unless increasing the costs. From a methodological perspective, however, there is not much developed on determining such a frontier or assessing the trade-offs in sustainable logistics networks, despite the extensive existing literature in the field of multi-objective programming. In this paper we address an approach that is sounded to capitalize the decision maker's most effective cognitive capabilities:visual representation. In order to explore the efficient frontier in feasible time (for the intractability of determining all extreme efficient solutions in a multi-objective linear program, see [11, 10, 2].

In every production process, whether agricultural or nonagricultural, inputs are used to create a finished product or commodity. Inevitably, some inputs are not fully used and are released into the environment in forms that may be considered pollutants. Whenever the level of pollution exceeds the environment's ability to absorb and process these discharges, environmental risks develop ([9])

In industries point of view, to handle waste would be the final step toward industrial pollution control. Nevertheless, there are different options available for managing waste, such as, reuse, recycle, incineration and landfilling. It is to be noted that incineration of waste is being discouraged worldwide because of the generation of toxic substances such as furans and dioxins in the environment. The waste management hierarchy of prevention, reuse, recycle and disposal in a landfill is accepted as a universal guideline for waste management. However, when it is desirable to shift from one stage of hierarchy to another, would depend on several factors such as cost, impact to the environment and risk perceived by the public. For minimization of environmental impact the ideal scenario would be maximum possible reuse and disposal in a landfill only when it cannot be reused or recycled. Typically that would mean maximum possible time span of life cycle of waste. The case would be the same while minimizing perceived risk, as it has been observed that, people perceive minimum risk for reuse and maximum for disposal in a landfill. As recycling is a preferred option than disposal in a landfill for the objectives of minimization of environmental impact and perceived risk, recycling of the waste would be preferred even after it is no longer economically attractive than disposal. [3] used the concept of industrial ecology, particularly in handling waste using recycling and reuse system for crude palm oil industry.

The objective of this paper is to propose a multiobjective programming model for managing business environmental risk in a crude palm oil manufacture which gives the best possible configuration of waste management facilities and allocates wastes to these facilities, to achieve the required objectives (minimization of cost, minimization of perceived risk (PR), minimization of environmental impact (EI) or a compromise between cost, PR and EI in such a way to limit its environmental consequences while increasing profitability.

2. Crude Palm Oil Manufacturing

2.1 Production Process

The two main products derived from the oil palm fruit are crude palm oil (CPO) and crude palm kernel oil (CPKO). CPO is obtained from the mesocarp (fiber) and CPKO is obtained from the endosperm (kernel). Each oil mill applies a conventional oil milling process, beginning with the steaming of fresh fruit bunches (FFB) under high pressure (sterilization) for a prescribed period of time to condition the fruits. The sterilized bunches are then threshed to separate the fruits from the bunch stalks. The fruits are subsequently pressed to obtain the crude oil. This oil–water mixture undergoes a separation process before the oil is purified and dried prior to storage. The water phase forms the bulk of the raw palm oil mill effluent, which is treated in a waste water treatment plant or a treatment pond.

2.2 Environmental Problems

The entire crude palm oil process does not need any chemicals as a processing aid. However, there are a number of environmental problems at the factories, such as high water consumption, the generation of a large amount of wastewater with a high organic content, and the generation of a large quantity of solid wastes and air pollution. The waste generation (per ton FFB production) from the crude palm oil industry shows that only 22.8% of the raw material input consists of valuable products (CPO and CPKO). Palm oil mills also produce significant quantities of by-products/solid waste, such as empty fruit bunch, fibres, shell, decanter cake and ash from the boiler. Only 23% of raw materials are products, the rests are waste/ by-products. Most of the by-products can be reused in the production process or in other industries. Fibres (14%) are used as fuel in boilers to generate steam and energy, required for the mill operation. Shell (6%) and empty fruit brunch (EFB) (24%) are sold for use in other industries. However, there is a lot of solid waste that has to be treated before disposal. These wastes include 0.03 million ton/ year of decanter sludge and 0.05 million ton/ year of ash. The problems of solid waste management in factories are improper storage and handling of solid waste material and improper land application techniques or practices for solids waste. These wastes consequently cause bad smell and dust that affect the surrounding communities.

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2.3 Existing Industrial Ecosystems in the Crude Palm Oil Industry

The crude palm oil industry has developed a number of industrial ecosystem practices for its waste recycling. The nature of these practices can be divided into in-plant industrial ecosystem (clean technology) options and possibilities for external waste exchange, which includes recycling of wastes between the industrial sector and other sectors such as agriculture. There are various technical options for an industrial ecosystem approach.

Environmental impact of palm oil industry can occur due to the following event. In order to produce CPO there are five stages involve: plantation, CPO mills, palm kernel oil mills, refinery factories, and CPO. Get the FFBs from palm oil plantation using transportation to a CPO mill. In here, kernel, CPO and bio-wastes are produced. Afterward kernel and CPO are transported to a place for processing kernel and CPO to get palm oil products. In market people buy this products and use them. Some part of the palm oil products are wasted as municipal waste [5].

3. Model Formulation

We define the notation used as follows.

Ju_{ip}	Amount of waste type i at source p
KLR	Risk factor
$Kupt$	Cost of segregation per unit quantity of waste in time step (t)
Ku_{itp}	Cost of processing unit quantity of waste I at source p in time step (t)
Kru_{it}	Cost recovered from the sale of unit quantity of processable waste type i in time step (t)
Ku_{it}	Cost recovered from the sale of unit quantity of reusable waste type i in time step (t)
$Ksit$	Cost of storage per unit quantity of waste in time step (t)
Bmb	Capital cost for locating disposal facility (b)
$BMfo$	Capital Cost for locating processing facility *fo*
b	Disposal facility
$D_{(p\text{-}fo)}$	Distance between the source node (p) and processing facility (*fo*)
$D_{(fo\text{-}b)}$	Distance between the processing facility (*fo*) and disposal facility (b)
$D_{(p\text{-}b)}$	Distance between the source node (p) and disposal facility (b)
$D_{(p\text{-}p^1)}$	Distance between the source node (p) and reuse facility (p^1)
e	Total number of time steps
e^1	Total number of time steps in which primary waste *i* can arrive back as waste after a cycle of reuse
p	Source node
p^1	Reuse facility
Vc	Importance factor for chemical/component (c)
t	Time step
t^1	Time step in which primary waste (u) going for reuse in time step (t) arrives back as waste on source nodes
$FRdis.b_i$	Risk multiplication factor for disposal of waste type i at disposal facility (b)
$FRseg.p_i$	Risk multiplication factor for segregation of waste type i at source node (p)
$Fro.fo_i$	Risk Multiplication Factor for processing of waste type i at processing facility (*fo*)
$FRpi.p^1_i$	Risk Multiplication Factor for reuse of waste type i at reuse facility (p^1)
$FRsi.p_i$	Risk multiplication factor for storage of waste type i at source node (p)
FRa_i	Risk multiplication factor for transportation of waste type i
n	Total number of source nodes
n^1	Total number of reuse facilities
P_{it}	Period in units of time step for which waste type i is stored in time step (t)
NG_{itp}	Quantity of new primary waste type i generated in time step (t) at source node (p)
N_{itp}	Quantity of primary waste type i generated at source node (p) in time step (t)
N_{it^1p}	Quantity of primary waste type i coming after a cycle of reuse in time step (t^1)
$N_{it(p\text{-}b)}$	Quantity of primary waste type i at source node (p) in time step (t) going directly to disposal site b
$N_{it(p\text{-}p^1)}$	Quantity of primary waste type i generated at source node (p) in time step (t) going to reuse facility p^1
$N_{it(p\text{-}fo)}$	Quantity of processable waste type i (generated after segregation of primary waste types) at source node 'p' in time step 't' going to processing facility *fo*
$N_{it(p\text{-}b)}$	Quantity of processable waste type i (generated after segregation of primary waste types) at source node 'p' in time step (t) going to disposal facility (b)
$N_{it(fo\text{-}b)}$	Quantity of processable waste type i (generated after segregation of primary waste types) left as residue at processing facility in time step (t) going to disposal facility (b)
$N_{it(p\text{-}b)}$	Quantity of reusable secondary waste type i (generated after segregation of primary waste types) at source node (p) in time step (t) going to disposal facility (b)

$N_{it(p-p^1)}$ Quantity of reusable secondary waste type i at source node (p) in time step (t) going to reuse facility (p^1)

$N_{it(p-b)}$ Quantity of non-reusable, non-processable secondary waste type i at source node (p) in time step (t) going to disposal facility (b)

J_{fo} Total number of facilities for processing

$Rsit_{(p)}$ Ratio of stored waste to waste arriving at source node (p) in time step (t)

R_{it} Ratio of waste type u^1 which could be processed considering. its total quantity

fo Processing facility

Nb Total number of disposal facility

K_{it} Cost of transportation of waste type i per unit weight per unit distance in time step (t)

K_{bt} Cost of transportation for disposal waste type i per unit weight per unit distance in time step (t)

w_i Total number of waste type i

Zb Logical variable associated with disposal facility (b)

Zfo Logical variable associated with processing facility fo

The model for the management of logistic CPO with life cycle based approach. There are three objectives to be attained within multi-time step. We define 'time step' as period of time, for which the waste generation and associated costs per unit quantity of weight, for a management of logistic activity (transportation, storage, disposal, etc.) remain constant. The time step could be year, months or any other unit of time for which the waste generation and associated management costs are assumed constant. The three objectives addressed consist of: (i) minimization of total logistic operational cost, (ii) minimization of waste environmental impact (EI), and (iii) minimization of total risk perceived (PR) by the people. Each of these objectives can be minimized individually or a compromise solution using goal programming by assigning different weighting to each objective. The decision maker can assign different weightings to cost, PR and EI, depending on the governing socio-economic scenario. Various scenarios of different weightings to each of the objectives can also be analyzed to arrive at the various tradeoffs between these objectives.

The problem is subjected to the following constraints:

a. Mass balance of wastes at each node
b. Allowable capacities at various facilities.
c. Logical constraints at processing and disposal sites.

4. The Model

The problem is formulated as a multiobjective integer programming model. There are three objectives involve, i.e., Total of logistic operational cost, the cost related to risk, called perceived risk, and environmental impact of waste.

(A) Total of logistic operational cost.

$$TC_1 = \sum_{t=1}^{e}\sum_{p=1}^{n}\sum_{u=1}^{w}\left[\left\{N_{itp} - \sum_{b=1}^{Nb} N_{it(p-b)}\right\} \times K_{itp}\right] \quad (1)$$

This expression represents the cost of segregation at source node

$$TC_2 = \sum_{t=1}^{e}\sum_{p=1}^{n}\sum_{i=1}^{w}\left[Nut_{(p)} \times Ksit \times Rsit_{(p)} \times R_{it}\right] \quad (2)$$

Cost of storage at source node

$$TC_3 = \sum_{t=1}^{e}\sum_{b=1}^{n}\sum_{i=1}^{w}\sum_{fo=1}^{J_{fo}}\left[N_{it(p-fo)} \times K_{it} \times D_{(p-fo)}\right] + \sum_{t=1}^{e}\sum_{b=1}^{N_b}\sum_{i=1}^{w}\sum_{fo=1}^{J_{fo}}\left[N_{it(fo-b)} \times (1-R_{it}) \times Ku_{it} \times D_{(fo-b)}\right] \quad (3)$$

Cost of transportation of waste from source node to processing facilities and residue from processing facilities to disposal facilities

$$TC_4 = \sum_{t=1}^{e}\sum_{p=1}^{n}\sum_{i=1}^{w}\sum_{fo=1}^{Jfo}\left[N_{it(p-fo)} \times K_{it}\right] \quad (4)$$

Representing the cost of processing waste at processing facilities

$$TC_5 = \sum_{fo=1}^{J_{fo}}\left[BMfo \times Zfo\right] \quad (5)$$

This is for Capital cost needed for locating processing facilities

$$TC_6 = \sum_{t=1}^{e}\sum_{p=1}^{n}\sum_{p^1}^{n^1}\left[\left\{\sum_{i=1}^{w} N_{it(p-p^1)} \times Ku_{itp} + \sum_{u^1=1}^{w^1} N_{it(p-p^1)} \times Ku_{it}\right\} \times D_{(p-p^1)}\right] \quad (6)$$

The transportation cost of reusable waste types to reuse facilities

$$TC_7 = \sum_{t=1}^{e}\sum_{i=1}^{w}\sum_{p=1}^{n}\sum_{b=1}^{nb}\left[N_{it(p-b)} \times Ku_{it} \times D_{(p-b)}\right] \quad (7)$$

Another transportation cost for some portion of waste from source nodes to disposal facilities

$$TC_8 = \sum_{b=1}^{Nb} \left[BMb \times Zb \right] \tag{8}$$

Capital cost for locating disposal facilities

$$TC_9 = \sum_{t=1}^{e} \sum_{b=1}^{Nb} \left[\sum_{p=1}^{n} \left\{ \sum_{i=1}^{w} N_{it(p-b)} \right\} \times K_{bt} \right] + \sum_{t=1}^{e} \sum_{b=1}^{Nb} \left[\sum_{i=1}^{w} \left\{ \sum_{p=1}^{n} N_{it(p-b)} + \sum_{fo=1}^{J_{fo}} N_{it(fo-b)} \right\} \times Kbt \right] \tag{9}$$

Representing the cost of waste disposal

$$TC_{10} = -\sum_{t=1}^{e} \sum_{i=1}^{w} \sum_{p=1}^{n} \sum_{fo=1}^{J_{fo}} \left[N_{it(p-fo)} \times Kru_{it} \times R_{it} \right] \tag{10}$$

This is for the cost recovered from the sale of recyclable portion of generated waste, therefore there is a negative sign.

$$TC_{11} = -\sum_{t=1}^{e} \sum_{i=1}^{w} \sum_{p=1}^{n} \sum_{p^1=1}^{n^1} \left[N_{it(p-p^1)} \times Ku_{it} \right] \tag{11}$$

Another cost recovered from the sale of reusable portion of generated waste.

(B) Total perceived risk (PR)

$$PR_1 = \sum_{t=1}^{e} \sum_{i=1}^{w} \sum_{p=1}^{n} \sum_{fo=1}^{J_{fo}} \left[N_{it(p-fo)} \times FRa_i \times KLR \right] \tag{12}$$

This is an expression for risk due to transportation of waste from generation nodes to processing facilities

$$PR_2 = \sum_{t=1}^{e} \sum_{p=1}^{n} \sum_{p^1=1}^{n^1} \left[\left\{ \sum_{i=1}^{w} N_{it(p-p^1)} \times FRa_{(u)} \right\} \times KLR \right] \tag{13}$$

Risk due to transportation of reusable portion of waste to reuse facilities

$$PR_3 = \sum_{t=1}^{e} \sum_{i=1}^{w} \sum_{b=1}^{Nb} \sum_{p=1}^{n} \left[N_{it(p-b)} \times FRa_i \times KLR \right] \tag{14}$$

Risk due to transportation of non-reusable waste from source nodes to disposal

$$PR_4 = \sum_{t=1}^{e} \sum_{i=1}^{w} \sum_{b=1}^{nb} \sum_{p=1}^{n} \left[N_{it(p-b)} \times FRdis.b_i \times KLR \right] \tag{15}$$

PR due to transportation of waste directly going to disposal without segregation

$$PR_5 = \sum_{t=1}^{e} \sum_{p=1}^{n} \sum_{i=1}^{w} \left[\left\{ N_{it(p)} - \sum_{b=1}^{Nb} N_{it(p-b)} \right\} \times FRseq.p_i \times KLR \right] \tag{16}$$

Risk at source nodes due to segregation

$$PR_6 = \sum_{t=1}^{e} \sum_{p=1}^{n} \sum_{i=1}^{w} \left[N_{it(p)} \times Rsit_{(p)} \times FRsi.p_i \times KLR \right] \tag{17}$$

Risk occurring at source nodes due to storage

$$PR_7 = \sum_{t=1}^{e} \sum_{b=1}^{Nb} \left[\sum_{p=1}^{n} \left\{ \sum_{i=1}^{w} N_{it(p-b)} \times FRdis.b_i \times KLR \right] + \sum_{t=1}^{e} \sum_{b=1}^{Nb} \left[\sum_{i=1}^{w} \left\{ \sum_{p=1}^{n} N_{it(p-b)} + \sum_{fo=1}^{J_{fo}} N_{it(fo-b)} \times FRdis.b_i \times KLR \right\} \right] \tag{18}$$

Risk at disposal facilities due to waste

$$PR_8 = \sum_{t=1}^{e} \sum_{p=1}^{n} \sum_{i=1}^{w} \sum_{fo=1}^{J_{fo}} \left[N_{it(p-fo)} \times FRo.fo_i \times KLR \right] \tag{19}$$

Calculating risk at processing facilities

$$PR_9 = \sum_{t=1}^{e} \sum_{p^1=1}^{n^1} \sum_{p=1}^{n} \left[\left\{ \sum_{i=1}^{w} N_{it(p-p^1)} \times FRpu.p^1{}_i \right\} \times KLR \right] \tag{20}$$

Risk at reuse facilities

(C) Total impact or risk of the environment

$$EI = \sum_{t=1}^{e} \sum_{b=1}^{Nb} \left[\sum_{p=1}^{n} \left\{ \sum_{i=1}^{w} \left| N_{it(p-b)} \times \sum_{m=1}^{cm} fu_{ip} \times V_c \right| \right\} \times Pk_{(b)} \right] + \sum_{t=1}^{e} \sum_{b=1}^{Nb} \left[\sum_{i=1}^{w} \left\{ \sum_{p=1}^{n} N_{it(p-b)} + \sum_{fo=1}^{Jfo} N_{it(fo-b)} \right\} \times \sum_{m=1}^{cm} \left(fu_{ip} \times V_c \right) \times Pk_{(b)} \right] \tag{21}$$

Constraints

(a) Mass balance for primary waste type going for reuse in time step t and arriving at source nodes in time step t^1

$$\sum_{p=1}^{n} \sum_{p^1=1}^{n^1} N_{it(p-p^1)} = \sum_{t^1=1}^{e^1} \sum_{p=1}^{n} N_{it^1(p)} \qquad \forall t, i \tag{22}$$

(b) Mass balance for waste arriving at source nodes

$$NG_{itp} + \sum_{t^1=1}^{e^1} N_{it^1p} = N_{itp} \qquad \forall t^1 = t,\ \forall p, \mathrm{i} \tag{23}$$

(c) Mass balance at source nodes

$$\sum_{t=1}^{e}\sum_{i=1}^{w} N_{itp} = \sum_{t=1}^{e}\left[\sum_{b=1}^{Nb}\left\{\sum_{i=1}^{w} N_{it(p-b)}\right\} + \sum_{p^1=1}^{n^1}\sum_{i=1}^{w} N_{it(p-p^1)} + \sum_{fo=1}^{J_{fo}}\sum_{i=1}^{w} Nu^1t_{(p-fo)}\right] \quad \forall p \tag{24}$$

(d) Mass balance at processing facilities

$$\sum_{p=1}^{n}\sum_{i=1}^{w}\left[N_{it(p-fo)} \times (1-R_{it})\right] = \sum_{i=1}^{w}\sum_{b=1}^{Nb}\left[N_{it(fo-b)}\right] \quad \forall fo,\ t \tag{25}$$

e) Capacity constraint at processing facilities

$$\sum_{p=1}^{n}\sum_{i=1}^{w}\left[N_{it(p-fo)}\right] \le Cap.fo.t \qquad \forall fo,\ t \tag{26}$$

(f) Logical constraint at processing facilities

$$\left[\sum_{t=1}^{e}\sum_{p=1}^{n}\sum_{i=1}^{w}\left[N_{it(p-fo)}\right] \Big/ \sum_{t=1}^{e}\sum_{i=1}^{w} N_{it(p)}\right] \le Zfo \le \sum_{t=1}^{e}\sum_{p=1}^{n}\sum_{i=1}^{w}\left[N_{it(p-fo)}\right] \quad \forall fo \tag{27}$$

(g) Capacity constraint at disposal facilities

$$\sum_{fo=1}^{J_{fo}}\sum_{i=1}^{w} N_{it(fo-b)} + \sum_{p=1}^{n}\left[\sum_{i=1}^{w} N_{it(p-b)}\right] \times Cap.b.t \qquad \forall b,\ t \tag{28}$$

(h) Logical constraint at disposal facilities

$$\left[\sum_{t=1}^{e}\left[\sum_{fo=1}^{J_{fo}}\sum_{i=1}^{w} N_{it(fo-b)} + \sum_{p=1}^{n}\left\{\sum_{i=1}^{w} N_{it(p-b)}\right\}\right] \Big/ \sum_{t=1}^{e}\sum_{i=1}^{w}\left[N_{it(p)}\right]\right] \le Zb \le \sum_{t=1}^{e}\left[\sum_{fo=1}^{J_{fo}}\sum_{i=1}^{w} N_{it(fo-b)} + \sum_{p=1}^{n}\left\{\sum_{i=1}^{w} N_{it(p-b)}\right\}\right] \qquad \forall b \tag{29}$$

(i) Capacity constraint at reuse facilities

$$\sum_{p=1}^{n}\sum_{i=1}^{w}\left[N_{it(p-p^1)}\right] \le cap.p^1.t \qquad \forall p^1, t \tag{30}$$

(j) Logical constraint

$$Zfo = 0 \quad or \quad 1$$

$$Zb = 0 \quad or \quad 1$$

5. Algorithm

The proposed interactive algorithm consists of the following three steps.

Steps 1. Determine an initial (weak) efficient solution.

Steps 2. Show the solution to the decision maker (DM). If DM is satisfied with the solution, (23)
Stop: otherwise, ask the DM to specify a new reference point $\bar{f}_k$, using Analytic Hierarchy Process (AHP) and go to step 3.

Steps 3. Based on the values of $\bar{f}_k$ and f_k (the last solution), solve (24)

$$\max y$$

subject to

$$f_k(x) - (\bar{f}_k - f_k)y \ge f_k, k \in H, \quad (25)$$

$$f_k(x) - \bar{f}_k + \alpha(\bar{f}_k - f_k), k \in H,$$

$$f_k(x) = \bar{f}_k, k \in E$$

$$x \in X$$

$$y \ge 0 \quad (26)$$

where y is a scalar.

and find a new intermediate weak efficient (or efficient)

solution $f_k(x)$; go to Step 2.

6. Conclusion

(27)

Managing business environmental risk in agro-industry consists of making the production process more efficient in such a way as to limit its environmental (28) consequences while increasing profitability.

In this paper we present a multi-objective integer programming model for managing business environmental risk in a crude palm oil manufacture which consists of making the production process more efficient (29) in such a way to limit the impact of environmental consequences and to meet the investment risk (perceived risk), and then we propose an interactive algorithm for solving the model.

References

(30)

[1] Bloemhof-Ruwaard,J.M, Krikk, H., and Van Wassenhove L.N, "*OR models for eco-eco closed-loop supply chain optimization., volume 1 of Reverse Logistics: Quantitative Models for Closed-Loop Supply Chains*", 2004, Springer-Verlag, Berlin/Heiderberg, 1 edition.

[2] Boyer O, Tang Sai Hong, Pedram A, Mohd Yusuff R, Zulkifli N, "A mathematical model for the industrial hazardous waste location-routing problem", *Journal of Applied Mathematics*, 2013, Article ID 435272.

[3] Chavalparit O, W.H. Rulkens, A.P.J. Mol, S. Khaodair, "Options for environmental sustainability of the crude palm oil industry in Thailand through enhancement of industrial

ISSN 2348 – 7968

ecosystems ", Journal Environment, Development and Sustainability, Vol. 8(2), 2006:271-287.

[4] Gopal,J., "The Development of Malaysia's Palm Oil Refining Industry: Obstacles,Policy, and Performance", Ph.D Thesis of the University of London and Diploma of Imperial College, England, 2001.

[5] Hayashi K, "Environmental impact of palm oil industry in Indonesia", Proceed. Of Int. Symposium on EcoTopia Science,ISETS07 2007.

[6] Huppes,G and M. Ishikawa, "A framework for quantified eco-efficiency analysis", *Journal of Industrial Ecology*, 9(4), 2005, 25-41.

[7] Liu, K and Shyng, Q, " *Eco-system in the steel industry*", Published in Proceeding of International Conference on Cleaner Production and Sustainable Development' 99. December 1999, Taipei,Taiwan.

[8] Quariguasi Frote Neto, J., Walther, G., Bloemhof, J., van Nunen, J.A.E.E & Spengler, T. A Methodology for assessing eco-efficiency in logistic networks. *European Journal of Operational Research*, 193(3), 2009: 670-682.

[9] Stavins, R. "Environmental Economics", Faculty Research Working Paper Series, Harvard University, 2004.

[10] Steuer,R.E and C. A. Piercy, "A regression study of the number of efficient extreme points in multiple objective linear programming", *European Journal of Operational Research*; 162(2), 2005, 484-496.

[11] Steuer,R.E.," Random problem generation and the computation of efficient extreme points in multiple objective linear programming", *Computational Optimization and Applications*; 3, 1994, 333-347.